



PATENT

Attorney Docket No.: SSI-00700

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:) Group Art Unit: 1763
Maximilian A. Biberger et al.) Examiner: Ram N. Kackar
Serial No.: 09/704,641) **TRANSMITTAL LETTER**
Filed: November 1, 2000) 162 North Wolfe Road
Sunnyvale, CA 94086
For: **METHOD AND APPARATUS FOR**) (408) 530-9700
SUPERCritical PROCESSING)
OF A WORKPIECE)

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Sir:

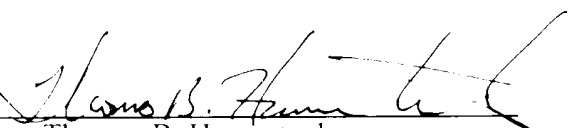
Enclosed please find a Reply Brief in triplicate in response to the Examiner's answer mailed on March 25, 2003 and a Request for Oral Hearing for filing with the U.S. Patent and Trademark Office. Also attached is a check in the amount of \$280.00.

The Commissioner is authorized to charge any additional fee or credit any overpayment to our Deposit Account No. 08-1275. **An originally executed duplicate of this transmittal is enclosed for this purpose.**

Respectfully submitted,
HAVERSTOCK & OWENS LLP

Dated: May 23, 2003

By:


Thomas B. Haverstock
Reg. No.: 32,571

Attorneys for Applicants

CERTIFICATE OF MAILING (37 CFR § 1.8(a))

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HAVERSTOCK & OWENS LLP.

Date: 5/23/03

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Sir:

In response to the Examiner's Answer, mailed March 25, 2003, this Reply Brief is submitted in triplicate. The Applicants submit this Reply Brief to the Board of Patent Appeals and Interferences in compliance with the requirements of 37 C.F.R. § 1.193(b).

I. THE PENDING ISSUES

Within the Examiner's Answer, the rejection of claims 1-25, 29, and 30 under 35 U.S.C. § 112 were withdrawn. Accordingly, the only issue pending on appeal is whether claims 1-25, 29, and 30 are improperly rejected under 35 U.S.C. § 103.

Within the Examiner's Answer:

- Claims 1-10, 13, 15-17, 19-20, 22-25, and 29 are rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Number 6,110,232 to Chen (Chen) in view of U.S. Patent Number 5,979,306 to Fujikawa (Fujikawa).
- Claim 20 is also rejected as being drawn to an intended use.
- Claims 18 and 21 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Chen in view of Fujikawa as applied to claim 16 and further in view of U.S. Patent Number 5,928,289 to Jevtic (Jevtic).
- Claim 30 is rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent Number 5,882,165 to Maydan (Maydan) in view of Fujikawa.

Within the Examiner's Answer, it is stated that claims 1-10, 15-25, 29, and 30 are rejected. Claims 11, 12, and 14 are not discussed. It is unclear whether the rejection of claims 11, 12, and 14 have been withdrawn.

II. INTRODUCTION

The invention disclosed in the pending application (the '641 application) is directed to an apparatus for performing supercritical and non-supercritical processing of a workpiece on a single cluster tool. The apparatus thus processes a workpiece in one processing chamber at non-supercritical temperatures and pressures and further processes the workpiece in another processing chamber at supercritical temperatures and pressures.

The independent claim 1 recites an apparatus comprising a transfer chamber, a supercritical processing module, and a non-supercritical processing module. Claims 2-25 depend from claim 1. The independent claim 29 recites a means for supercritical processing, a means for non-supercritical processing, and a means for transferring a workpiece into a transfer module and into both the supercritical and non-supercritical modules. The independent claim 30 recites a

supercritical processing module, a non-supercritical processing module, a hand-off station, and a transfer mechanism for transferring a workpiece between the supercritical processing module, the non-supercritical processing module, and the hand-off station.

Fujikawa teaches a stand-alone apparatus for performing high-pressure processing of a substrate. In its section titled "Field of Invention," Fujikawa briefly mentions supercritical processing but makes no further mention of this nor describes how supercritical processing is performed. Chen teaches a method of performing non-supercritical processing in a cluster tool having a transfer chamber. There is no teaching, hint, or suggestion that the modules attached to the cluster tool in Chen can or should operate at pressures different from each other. Maydan teaches a vacuum-integrated cluster tool having only non-supercritical processing modules.¹ Neither Fujikawa nor Chen nor Maydan teaches coupling a supercritical processing module with a non-supercritical processing module on a single cluster tool. Moreover, since there is no teaching, hint, or suggestion of using modules that process at different pressures, combining these references can neither result in the present invention nor render it obvious.

Throughout the Examiner's Answer, it is admitted that none of the cited prior art teaches a supercritical processing module coupled to a non-supercritical processing module in a cluster tool. For example, at page 7 of the Examiner's Answer, it is stated, "It is agreed that alone neither Chen nor Fujikawa teach[es] a combination of supercritical and non-supercritical modules on a single cluster tool." And at page 5 of the Examiner's Answer, it is stated, "Maydan et al do not disclose a supercritical module coupled to a hand off station." Nevertheless, within the Examiner's Answer it is stated that there is motivation to combine Fujikawa with Chen or Maydan to produce the invention disclosed in the '641 application, ignoring the fact that neither Chen nor Maydan teaches processing modules in a cluster tool operating at different pressures. As discussed below, no such teaching, suggestion, or motivation exists. Accordingly, the rejection of the independent claims 1, 29, and 30 is improper and should be withdrawn. Furthermore, because claims 2-25 depend from allowable claim 1, the rejection of these claims should also be withdrawn.

¹Atmospheric pressure is approximately 15 psi. Vacuum pressure can be smaller, such as 0 psi for a complete vacuum. As disclosed in the '641 application at page 10, lines 8-9, supercritical pressures can reach 2,800 psi. Thus, pressures for supercritical processes are vastly different than those used for processes operating at vacuum or at atmosphere.

III. ARGUMENT

A. THE GROUNDS FOR REJECTION ARE ESSENTIALLY
THOSE FROM THE FINAL OFFICE ACTION AND HAVE BEEN
RESPONDED TO IN THE APPEAL BRIEF.

Within the Examiner's Answer, the section titled "Grounds of Rejection" repeats the grounds for rejection set forth in the final Office Action mailed on October 25, 2002, and adds one more point. The Applicants' response to these arguments were stated in the Applicants' Appeal Brief, filed on February 20, 2003, and will not be repeated in their entirety here.

Within the Examiner's Answer, one additional point is made: While admitting that Chen does not disclose a supercritical module connected to it, the Examiner's Answer states that "Chen et al disclose spare capacity to connect additional future process modules to its transfer module (Col 1 lines 44-46)." [Examiner's Answer at page 4] This argument leaps to the unsupportable conclusion that a combination of devices can render an invention obvious when they are *capable* of being coupled to each other. The question before the Board is not whether two components are capable of being coupled but whether there is any teaching, suggestion, or motivation to do so. As stated above and below, and also in the Appeal Brief, the prior art does not provide any teaching, suggestion, or motivation to combine a supercritical processing module with a non-supercritical processing module, as taught in the '641 application.

Further, within the Examiner's Answer, is stated that goals of keeping a substrate in a clean environment and reducing cycle time provide sufficient motivation to combine Fujikawa and Chen. [Examiner's Answer at pages 4 and 7-8] As shown below and in the Appeal Brief, this conclusion ignores evidence that one skilled in the art would not have found and did not find it obvious to combine Fujikawa with either Chen or Maydan.

B. THE COMBINATION OF FUJIKAWA AND CHEN
DOES NOT RENDER CLAIMS 1 AND 29 OBVIOUS.

1. The Examiner's Answer does not overcome the
assertions by one skilled in the art that the invention
of the '641 application is nonobvious.

The Appeal Brief relies in part on a declaration from Dr. Moslehi, one skilled in the art, to prove that the claims in the '641 patent application are nonobvious to one skilled in the art. [Appeal Brief, attachment 5] Specifically, within his declaration, Dr. Moslehi concludes, among other things, that when the '641 application was filed, one skilled in the art would have found no motivation to combine Chen and Fujikawa to produce a cluster tool having a supercritical processing module and a non-supercritical processing module as taught in the '641 application. [E.g., Moslehi Decl. ¶30] Moreover, Dr. Moslehi found that "[s]imply attaching the devices taught in Fujikawa, Chen, and Jevtic would not work." [Id., ¶ 21] For at least this reason, claims 1 and 29 are allowable over the cited references. Additionally, because claim 2-25 depend from claim 1, they too are allowable as depending from an allowable base claim.

Within the Examiner's Answer it is noted that "The appeal brief draws heavily from the declaration of Dr. Moslehi." [Examiner's Answer at page 6] Under the U.S. patent laws and the rules that govern practice before the U.S. Patent Office, the testimony of one skilled in the art is highly relevant to questions of obviousness, which are determined in light of one skilled in the art. Dr. Moslehi's declaration is relied on, as it should be. [See, e.g., *Environmental Designs, Ltd. v. Union Oil Co. of California*, 713 F.2d 693, 697 (Fed. Cir. 1983), *cert. denied*, 464 U.S. 1043 (1984) ("The important consideration lies in the need to adhere to the statute [35 U.S.C. § 103], i.e., to hold that an invention would or would not have been obvious, as a whole, when it was made, to a person of 'ordinary skill in the art'—not to the judge, or to a layman, or to those skilled in remote arts, or to geniuses in the art at hand.")].

As an additional point, within the Examiner's Answer it is stated, "Use of [an] additional transfer chamber is common to do preprocessing in an optimized scheduling environment to increase throughput." [Examiner's Answer at page 5] Jevtic is cited to support for this statement. The Applicants disagree with this conclusion for at least two reasons.

First, as described in the Applicants' Appeal Brief, Jevtic does not teach an antechamber as recited in claim 18 of the '641 application. [See Appeal Brief at pages 18-22] Moreover, as explained more fully in the Appeal Brief [id.] and below, an antechamber as used in the '641

patent application differs from the transfer chamber taught in Jevtic. The two have different purposes, requirements, and structures. The transfer chamber in Jevtic abuts multiple processing chambers, providing a common chamber from which to access multiple processing chambers. It is correspondingly a large chamber. In contrast, the antechamber taught in the '641 application abuts only a transfer chamber and a single processing chamber. It is designed in part to reduce contamination introduced into processing chambers and to be pressurized and depressurized quickly. As stated in the provisional patent application that the '641 application incorporates by reference, "The purpose of the [ante-chamber] is to reduce the pressurized volume of the system to a minimum."² Furthermore, unlike the transfer chamber taught in Jevtic, the ante-chamber isolates chambers operating at different pressures.

For the above reasons, any conclusion that the transfer chamber of Jevtic and the antechamber of the '641 application are equivalent is unfounded. Accordingly, claim 18 is allowable over the combination of Jevtic, Chen, and Fujikawa. Claim 18 is allowable for at least the additional reason that it depends from claim 1, an allowable base claim.

2. Fujikawa teaches nothing about supercritical processing.

At page 7 of the Examiner's Answer, three points are made:

- Fujikawa "could do washing in a supercritical state."
- It is irrelevant that Fujikawa does not teach supercritical processing because the claims relate to an apparatus and not a process.
- The supercritical and non-supercritical modules are not claimed to be attached to each other directly.

The Applicants respectfully disagree with each of these points.

²Page 7 of U.S. provisional patent application Serial Number 60/163,121, filed November 2, 1999, and titled "A High Throughput Cluster Tool for Cleaning Semiconductor Devices Using Supercritical CO₂" (the '121 provisional application), which is attached hereto as Exhibit A. The '641 application claims priority from and incorporates by reference the '121 provisional application.

First, Fujikawa makes one passing reference to supercritical processing in its section titled "Field of the Invention." No further mention of supercritical processing can be found in Fujikawa and, within the Examiner's Answer, no other portion of Fujikawa is cited as teaching supercritical processing. A mere recitation of supercritical processing, with no teaching of how to do so, cannot support a finding that Fujikawa teaches supercritical processing as taught in the '641 application.

Second, within the Examiner's Answer, it is stated, "The point about Fujikawa not teaching supercritical processing is not commensurate to the scope of the claims as the claims being examined relate to an apparatus and not a process." Fujikawa is analyzed for what it teaches because an application is read in light of what it teaches, in its entirety, to one skilled in art. For example, if Fujikawa taught how to perform supercritical processing, it arguably could teach one skilled in the art sufficient structure to perform supercritical processing. It could arguably do this without reciting valves and other structure. However, Fujikawa teaches no such thing and thus gives no hint as to the structure used to perform supercritical processing, let alone a structure used to couple a supercritical processing module to a non-supercritical processing module. Moreover, Fujikawa does not provide any teaching, hint, or suggestion of a cluster tool.

In contrast, the '641 application teaches steps to perform supercritical processing, temperature ranges, and the like. [See, e.g., '641 application, Figure 3, page 9, lines 27-31 and page 10, lines 2-13] One skilled in the art found such information critical and sufficient to practice the invention taught in the '641 application. [See, e.g., Moslehi Decl. ¶ 23]

Third, within the Examiner's Answer it is stated, "the supercritical module and the non-supercritical modules are not claimed to be attached to each other directly. As discussed before[,] Fujikawa alone does not teach both a supercritical and a non-supercritical module attached to a cluster tool." This passage is confusing. If it means that the '641 application arguably teaches a supercritical module and a non-supercritical module as separate, unattached components, the Applicants disagree with such an interpretation. Claim 1 of the '641 application clearly recites that the supercritical module and the non-supercritical module are coupled by a transfer chamber. The question remains whether, as of the filing date, there was any motivation to couple them and the knowledge how to do so. As argued here and in the Appeal Brief, the Applicants respectfully submit that there was no motivation to couple them, using an antechamber or using any other means.

3. Within the Examiner's Answer, the solution taught in the '641 application is impermissibly used as a starting point to find obviousness-Hindsight reconstruction is not allowed.

At page 8 of the Examiner's Answer, it is stated:

Fujikawa has very clearly disclosed the connection of a high-pressure module to a robot arm in vacuum (Col 7 lines 23-29). If the high-pressure module connects to the cluster tool of Chen et al it would connect only to a transfer module. . . . The specification does not disclose any structural features which would imply anything beyond these prior art disclosed valves and seals to prevent gas leak and cross-contamination.

Simplified, this argument from the Examiner's Answer is (1) if two processing modules are connected, then they must be connected using a transfer module; and (2) however there is no structural teaching to do so. The Applicants respectfully disagree with these conclusions. Prong one of this argument assumes that one found a motivation, teaching, or suggestion to connect a supercritical processing module and a non-supercritical processing module, and then concludes that once this assumption is made, the solution is found in the prior art. However, as argued above and in the Appeal Brief, no such assumption should be made because the prior art offers no teaching, suggestion, or motivation to connect a supercritical processing module with a non-supercritical processing module, as taught and claimed in the '641 application. The Examiner's Answer impermissibly assumes that which is to be proved.

As to the second prong, it is stated that the specification does not disclose any novel structural features. But as stated in the Appeal Brief, the specification must be read for what it teaches one skilled in the art. [E.g., Appeal Brief at pages 5-8] As stated in the Appeal Brief, the process steps, operating temperatures, and other information taught in the '641 application teach structural features used to practice the present invention. Indeed, in responding to an earlier rejection that the specification was non-enabling under 35 U.S.C. § 112, paragraph 1, the Applicants argued that the process steps, operating temperatures, and other information were sufficient to teach one skilled in the art the structural requirements of the present invention. [See Appeal Brief at pages 5-9] It is telling that in the Examiner's Answer, the rejection on these grounds has been withdrawn. Within the Examiner's Answer it has thus been recognized that

process requirements and the like teach one skilled in the art the novel structure claimed in the '641 application.

4. The Examiner's Answer suggests that because other cluster tools exist, the cluster tool taught in the '641 application is obvious.

Within the Examiner's Answer, it is stated that the advantages of cluster tools have been known for a long time; Chen is cited to support this statement. [Examiner's Answer at pages 8-9] Within the Examiner's Answer, it is further stated that the "Semiconductor Equipment and Materials International (SEMI)[] has developed standards to enable seamless integration of process modules *from different vendors* to a common transfer module in a cluster tool environment." [*Id.* at page 9, italics added]

That SEMI has enacted standards to connect components *from different vendors* is irrelevant. These standards may allow, for example, two atmospheric or low-pressure modules to be connected. Nowhere is it stated within the Examiner's Answer that when the '641 application was filed, SEMI had enacted standards for coupling a supercritical module and a non-supercritical module, as recited for example in claims 1, 29, and 30 of the '641 application.

Moreover, within the Examiner's Answer it is not stated whether any structures for coupling a supercritical processing chamber and a non-supercritical processing chamber to a transfer module, other than that taught in the '641 application, existed when the '641 application was filed, or even whether any exist today. As stated by Dr. Moslehi, no such cluster tools were available on the filing date and indeed, as far as he knows, no other such tools incorporating a supercritical processing module and a non-supercritical processing module existed when he filed his declaration. [Moslehi Decl. ¶ 14]. The undersigned is aware of no such system as of the date hereof.

C. CLAIM 20 RECITES STRUCTURE NOT INTENDED USE.

Within the Examiner's Answer, claim 20 is rejected as (1) directed to an intended use and (2) not structurally distinguishing over Fujikawa. [Examiner's Answer at pages 4 and 8] Claim 20 ultimately depends from claim 1 and further recites, "wherein the means for pressurizing

comprises a CO₂ pressurizing configuration which comprises a CO₂ supply vessel coupled to a pump which is coupled to the supercritical processing module.”

As argued in the Appeal Brief at pages 17-18, such language recites structure, not intended use. Moreover, because claim 20 depends from allowable claim 1, it too is allowable as depending from an allowable base claim.

D. AS TO CLAIM 18, THE EXAMINER’S ANSWER
DOES NOT ADDRESS, LET ALONE CHALLENGE THE
APPLICANTS’ ARGUMENTS THAT THE SPECIFICATION
SUPPORTS THEIR DEFINITION OF AN ANTE-CHAMBER.

Claim 18 ultimately depends from claim 1 and further recites, “further comprising an ante-chamber coupling the transfer module and the supercritical processing module.”

As to claim 18, the Examiner’s Answer completely ignores the arguments and supporting case law given in the Appeal Brief. Within the Examiner’s Answer, it is stated:

The specification has not provided any definition of antechamber except that it is a transfer chamber disposed between a process module and the main transfer module. [¶] Appellant argues that [the] transfer chamber of Jevtic could not be an antechamber because of not being small. [¶] Appellant has attributed characteristics to the antechamber, which are not supported by the specification. Regarding size, if the antechamber contains a robot it will have to be at least as big as the robot. Besides, transfer modules always have low height (See Chen et al Fig 1-20) and low volume to allow for fast evacuation and fast venting.

[Examiner’s Answer at pages 9-10]

This argument fails in several respects. First, the Examiner’s Answer ignores the requirement that the specification, including the drawings, is interpreted as would one skilled in the art. As stated within the Appeal Brief and Dr. Moslehi’s declaration, one skilled in the art found that the ‘641 application teaches that the ante-chamber recited in claim 18 “is a very small volume chamber. . . . The requirement of a small volume is essential for maximizing throughput and minimizing cross-contamination between the supercritical processing module and the non-supercritical processing modules.” [Moslehi Decl. ¶ 32] This finding is further supported within the ‘121 provisional application, which the ‘641 application incorporates by reference. Dr. Moslehi additionally found that the chamber in Jevtic does not teach, hint, or suggest these requirements. [Id.]

Second, the Examiner's Answer ignores controlling case law cited in the Appeal Brief, holding that the drawings in the '641 application can be used to support the interpretation that the ante-chamber have a small volume. [See Appeal Brief, page 22; see also *Vas-Cath Inc. v. Mahurkar*, 935 F.2d 1555, 1565 (Fed. Cir. 1991) ("under proper circumstances, drawings alone may provide a 'written description' of the invention"); *Advanced Cardiovascular Systems, Inc. v. Scimed Life Systems*, 96 F. Supp. 2d 1006, 1020 (N.D. Cal. 2000) (in determining that the phrase "substantially larger" is not indefinite, the court found that goal of flexibility and the figures in the application together taught a person skilled in the art the relative dimensions of an apparatus)] Moreover, the '121 provisional application clearly teaches a small ante-chamber. [See, e.g., '121 provisional application at page 7] Indeed, the Examiner's Answer does not even mention the arguments raised in the Appeal Brief and makes no attempt to rebut them. Accordingly, the Applicants submit that this rejection is now moot.

Third, the Examiner's Answer ignores the extra limitation placed on the chamber of Jevtic: that the chamber be large enough to allow access to multiple chambers. Thus, the chamber in Jevtic must be large enough and with multiple openings to allow access to multiple processing chambers. This is in contrast to the ante-chamber in the '641 patent application.

Fourth, within the Examiner's Answer it is further stated that Jevtic teaches the antechamber taught in the '641 application because "[u]se of [an] additional transfer chamber is common to do preprocessing in an optimized scheduling environment to increase throughput." [Examiner's Answer at page 5] This interpretation of Jevtic further highlights the differences between the transfer chamber taught in Jevtic and the ante-chamber taught in the '641 application. For example, Jevtic teaches a pre clean chamber (114, Figure 1) and a cool down chamber (102, Figure 1), both arguably used to further process a wafer. In contrast, in one embodiment taught in the '641 application, the ante-chamber is not used to process a wafer but as a buffer/isolation chamber. [See, e.g., Moslehi Decl. ¶¶ 17 and 31] The requirements and thus structures of a buffer/isolation chamber (i.e., ante-chamber) differ from those of a processing chamber taught in Jevtic.

For these reasons, the Examiner's Answer does not overcome the conclusion that Jevtic does not teach an antechamber as recited in claim 18 of the '641 application. For this additional reason, the rejection of claim 18 should be withdrawn. Furthermore, because claim 21 depends from claim 18, it is allowable as depending from an allowable base claim.

E. CLAIM 30 TEACHES STRUCTURE SIMILAR TO
THAT RECITED IN CLAIM 1 AND IS ALLOWABLE
FOR THE SAME REASONS AS CLAIM 1.

Claim 30 recites a supercritical processing module and a non-supercritical processing module both coupled to a hand-off station. Within the Examiner's Answer, Fujikawa is cited as teaching a supercritical processing module and Maydan is cited as providing a hand-off station. As stated in its Abstract, Maydan discloses a cluster tool having multiple vacuum processing chambers.

Neither Fujikawa nor Maydan provides any motivation, teaching, or suggestion to combine them to form the invention recited in claim 30. Indeed, as Dr. Moslehi states in paragraph 20 of this declaration:

Maydan is exclusively a vacuum-integrated cluster tool and does not have any reference to a supercritical processing module. The cluster tool disclosed in Maydan is only suitable for non-supercritical process modules. Maydan's cluster tool cannot be used for mounting a supercritical process module. Simply attaching the device taught in Fujikawa with the one taught in Maydan would not work.

Thus, neither Fujikawa, nor Maydan, nor their combination teaches or suggests claim 30. Nor is there any motivation to combine the references and then make further changes to form the structure of claim 30. Accordingly, claim 30 is allowable over Fujikawa combined with Maydan.

F. THE PROCESS STEPS TEACH HOW TO PRACTICE
THE INVENTION AND THUS TEACHES STRUCTURAL
LIMITATIONS TO ONE SKILLED IN THE ART.

Next, it is stated within the Examiner's Answer that "the process integration drivers do not appear to be referring to any structural limitation and therefore [are] not relevant to apparatus claims under rejection." [Examiner's Answer at page 10] Within the Examiner's Answer it is suggested that an apparatus claim cannot depend on process knowledge; that is, process knowledge does not define structure and thus will not determine whether an apparatus works properly. [*Id.*] The Applicants assume that the argument is raised that a structure will work whether an operator understands the process or not.

The Examiner's Answer misinterprets the reliance on the process description in the '641 application. As for structure, the process description and other operating parameters taught in the '641 application are used to teach one skilled in the art the steps used to practice the present invention. This knowledge, in turn, teaches one skilled in the art details of the structure used to practice the present invention. In other words, the process description and other operating parameters teach one skilled in the art more than just the process steps. They teach one skilled in the art the details of the corresponding structure.

III. CONCLUSION

For the above reasons, it is respectfully submitted that the claims 1-25, 29, and 30 are allowable over the cited prior art references. Therefore, a favorable indication is respectfully requested.

Respectfully submitted,
HAVERSTOCK & OWENS LLP

Dated: May 23, 2003

By: Thomas B. Haverstock
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Attorneys for Applicants

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- 13 -

HAVERSTOCK & OWENS LLP.
Date: 5/23/03 By: Thomas B. Haverstock

A HIGH THROUGHPUT CLUSTER TOOL FOR CLEANING SEMICONDUCTOR DEVICES USING SUPERCRITICAL CO₂

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FIELD OF THE INVENTION

The present invention relates to the field of high throughput cluster tools. More particularly, the cleaning of semiconductor devices using supercritical CO₂ (SCC), SCC plus additives, liquid CO₂ (LC), LC plus additives, being used in a high throughput cluster tool.

BACKGROUND OF THE INVENTION

The manufacture of semiconductor devices requires application and/or removal of photoresist (PR), photoresist residue (PRR) and/or etch (polymer) residue (ER). In order to remove PR, PRR or ER the current process flow employs a plasma ash process followed by a wet clean step as depicted in Figure 1:



Figure 1: Current process flow for the removal of PR

This process flow however, requires two different tool sets and the usage of big amounts of chemicals and water. A more environmentally friendly solution is proposed in this patent disclosure.

SUMMARY OF THE INVENTION

In this invention the term semiconductor devices encompasses the field of silicon wafer processing (e.g.: to manufacture silicon chips), the area of thin film transistors (TFT's for flat panel displays), magnetic and optical storage devices. In order to remove PR, PRR or ER the current process flow usually is to perform an ash process followed by a wet clean step as depicted in Figure 1.

The usage of SCC makes the ash and the wet clean step obsolete and reduces the number of cleaning steps required to one (instead of two). This can be seen in Figure 2:



Figure 2: Process flow for the removal of PR by using SCC cleaning

As one can see in Fig. 2, SCC cleaning allows to reduce the number of process steps to be reduced from two (2) to one (1), hence reducing the cost of manufacturing of a semiconductor device (or the like) and the possibility of wafer damage, while increasing yield.

In addition to reducing footprint in fabs, the usage of SCC reduces the amount of acids/solvents and water usage dramatically, providing huge environmental and cost benefits.

This cost saving however, will only take place if the throughput (TPT) of the equipment using the SCC cleaning technology is at least as high as the TPT of the ashing equipment and/or the wet cleaning equipment.

What is needed is a high throughput (cluster) tool to clean semiconductor devices with SCC.

In view of above discussion it is one object of the present invention to provide a transport system (backbone) for workpieces such as semiconductor wafers, flat panel displays, optical discs, magnetic storage devices or the like, which is configured to minimize the time required to bring workpieces from atmospheric pressure levels to pressure levels required for supercritical cleaning and back to atmospheric pressure levels.

It is a related object to provide a high pressure wafer processing backbone which enhances throughput by providing separate isolatable cleaning chambers that work in parallel (or in series) and can consist of single wafer or batch processing chambers.

It is another object of the present invention to provide a system that is adapted to minimize the pressurization time and thus increasing throughput for high pressure cleaning chambers, for instance for cleaning workpieces with photoresist on.

It is another object of the present invention to provide a system that can be adapted to a) existing oxide etch systems, b) to existing metal deposition systems (PVD, CVD and PVD/CVD), c) CMP systems and the like

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The detailed description of the preferred embodiments will be discussed in two sections. In section I) we will discuss the standalone (SA) application, i.e. the cleaning cluster tool is "between" the (oxide) etch tool and the metal deposition tool. In section II) we will discuss the integrated version, i.e. one or more SCC cleaning chambers are

connected to existing cluster tools either for (oxide/metal) etch, metal deposition (PVD, CVD and/or PVD/CVD), electrochemical deposition (ECD) or CMP or the like. Using the drawings shown in Figs. 3, 4, 5 and 6, the preferred embodiments are explained.

Section I: The "standalone" application

Figure 3 shows option 1 of the workpiece processing system as described above.

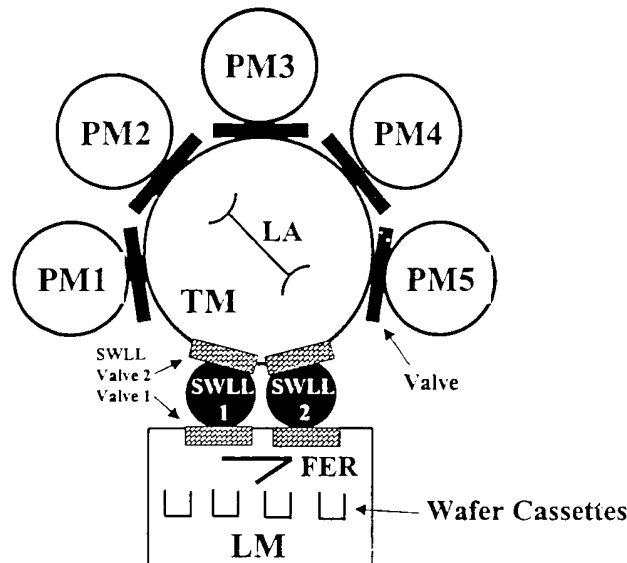


Figure 3: Sketch of option 1 for a workpiece processing system

The various components of the above system are explained as follows:

LM: Loader Module. Atmospheric module containing a variable number of cassette boxes for wafer sizes greater than 2 inch (e.g.: 3, 4, 5, 6, 8, 12 or greater) , or FOUP boxes for wafer sizes greater than 8 inch or cassettes for flat panel displays of various sizes, or cassettes for optical storage devices or the like. For some workpieces proper alignment is required. This alignment can be done in either the LM by adding a (e.g.: a commercially available) workpiece aligner or by aligning the workpieces in one of the single wafer load locks, or in the transfer module, or in one of the processing modules (PM). The loader module can be under atmospheric pressure as outlined above, or can be slightly overpressured by using

FER: Front End Robot arm. This robot arm is an atmospheric robot arm. This robot arm can be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the throughput (TPT) of the system by using suction devices such as vacuum or others.

SWLL: Single Wafer Load Lock. The workpiece processing system can contain one, two or more SWLL's, depending on the (backend) configuration and the desired TPT

The purpose of the SWLL is to transfer workpieces from the atmospheric front end to the high pressure backend (supercritical cleaning chambers). In the following an example is given as how to transfer workpieces from the atmospheric front end of the processing system to the high pressure backend. During the first step of the workpiece transfer the FER picks up a workpiece and transfers it into the SWLL (at that point SWLL Valve 2 is closed). After the workpiece is in the SWLL, SWLL Valve 1 also closes. Now that the workpiece is in the SWLL one or two of two things happens: a) if the (potentially required) alignment of the workpiece has not happened yet, it can be done in the SWLL and/or the pressurization of the SWLL occurs or, b) the alignment has already happened, then the pressurization of the SWLL occurs. After the SWLL is pressurized SWLL Valve 2 opens and the Loader Arm (LA) picks up the workpiece. The LA could be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the TPT of the system by using suction devices such as vacuum or others. One advantage of having valves on the SWLL's could be though, that sensing devices for PR, PRR and ER could be attached to the SWLL's. By valving off the SWLL before the semiconductor workpiece returns to the cassette, a measurement/sensing cycle could start during which one looks for PR, PRR and ER. If the workpieces were not cleaned completely a warning could occur and the system could be halted or returned into the cleaning cycle.

TM: Transfer Module. The purpose of this module is to house the LA which transfers the workpieces to the individual cleaning chambers. The number of ports on the TM can be one or higher. The final number of ports again depends on the (final) system configuration driven by the TPT requirements. A typical number of ports is anywhere between 1 and 6 chambers to warrant a TPT of more than 60 wafers per hour. The transfer module is pressurized to a pressure that is similar to the pressure in the cleaning chambers. This pressure is at least 1000 psi though.

PM: Process Module. The number of process modules depends on the TPT requirements, but is usually greater than two. After the workpiece has been picked up by the LA the PM valve opens and the workpiece is put into the process module. After the arm retracts the valve between the process module and the TM closes and the processing in the cleaning chamber(s) commences.

After the processing of the workpieces in the process module(s) (i.e. cleaning chambers) is completed, the TA picks up the workpiece from the PM and transfers it to SWLL 1 or 2 (or 3 or higher). Both options are possible. From a TPT point of view the latter option is the preferred one, because it allows higher TPT. Once in the SWLL valve 2 closes and the chamber gets de-pressurized. After that valve 1 opens and the wafer returns to its in its cassette.

Above concept would certainly provide a high TPT system. However, one potential drawback of the system as outlined in Fig. 3 is the great volume that needs to be under high pressure, such as the SWLL's, the TM and the PM's.

A simpler way to achieve a high TPT workpiece processing system is outlined as option 2 in Figure 4:

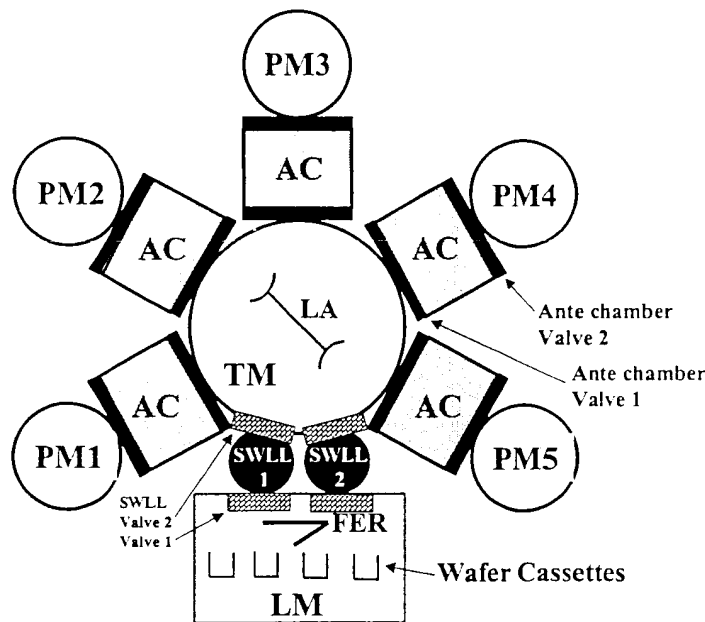


Figure 4: Sketch of option 2 for a workpiece processing system

The workpiece processing flow would be as follows:

LM: Loader Module. Atmospheric module containing a variable number of cassettes boxes for wafer sizes greater than 2 inch (e.g.: 3, 4, 5, 6, 8, 12 or greater) , or FOUNDRY boxes for wafer sizes greater than 8 inch or cassettes for flat panel displays of various sizes. For some workpieces proper alignment is required. This alignment can be done in either the LM by adding a (e.g.: a commercially available) workpiece aligner or by aligning the workpieces in one of the processing modules (PM). The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly overpressured with an inert gas or nitrogen or the like).

FER: Front End Robot arm. This robot arm is an atmospheric robot arm. This robot arm can be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the throughput (TPT) of the system by using suction devices such as vacuum or others.

SWLL: Single Wafer Load Lock. The workpiece processing system can contain one, two or more SWLL's, depending on the (backend) configuration and the desired TPT

The purpose of the SWLL is to transfer workpieces from the atmospheric front end to the high pressure backend (supercritical cleaning chambers). The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly overpressured with an inert gas or nitrogen or the like). In the following an example is given as how to transfer workpieces from the atmospheric front end of the processing system to the high pressure backend.

During the first step of the workpiece transfer the FER picks a workpiece and transfers it into the SWLL (at that point SWLL Valve 2 is closed. In this configuration valves are not really needed, because the whole front end of the system is under atmospheric pressure and the valve movements described would not be necessary). After the workpiece is in the SWLL, SWLL Valve 1 also closes. Now that the workpiece is in the SWLL the (potentially required) alignment of the workpiece could be performed, if it has not happened yet, in the LM. Pressurization of the SWLL in this case is not required, hence SWLL Valve 2 opens and the Loader Arm (LA) picks up the workpiece. The SWLL's in this configuration are considered more like handoff stations rather than SWLL's. The LA could be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the TPT of the system by using suction devices such as vacuum or others. One advantage of having valves on the SWLL's could be though, that sensing devices for PR, PRR and ER could be attached to the SWLL's. By valving off the SWLL before the semiconductor workpiece returns to the cassette, a measurement/sensing cycle could start during which one looks for PR, PRR and ER. If the workpieces were not cleaned completely a warning could occur and the system could be halted or returned into the cleaning cycle.

A more efficient and faster way to transfer the workpieces is described below: The workpiece is transferred via the FER into the SWLL. In this scenario the SWLL(s) do not have SWLL valves, because the backbone is not pressurized, hence no pressurization is required. After the workpiece has been picked up by the FER and placed in the SWLL (hand off station) the (potentially required) alignment of the workpiece could be performed, if it has not happened yet, in the LM. In this scenario the SWLL (s) are used solely as handoff and or handoff / alignment stations. Now the Loader Arm (LA) picks up the workpiece. The LA could be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the TPT of the system by using suction devices such as vacuum or others. The SWLL's could be slightly overpressured (similar to the LM) in order to avoid particulate contamination

TM: Transfer Module. The purpose of this module is to house the LA which transfers the workpieces to the individual cleaning chambers. The number of ports on the TM can be one or higher. The final number of ports again depends on the (final) system configuration driven by the TPT requirements. A typical number of ports

is anywhere between 1 and 6 chambers to warrant a TPT of more than 60 wafers per hour. The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly overpressured with an inert gas or nitrogen or the like). The workpiece(s) are now on the LA and are ready to be placed into the antechamber (AC)

AC: Antechamber. The purpose of the AC is to reduce the pressurized volume of the system to a minimum. After the workpieces were placed on the LA and before opening the valve(s) to the AC, pressure equilibrium between the AC and the TM has to be established. In order to do that valve 1 and 2 close and the AC gets depressurized. Preferably to a pressure that is similar to the TM pressure. One might wish though that the TM pressure is slightly higher than then AC pressure, in order to avoid contaminants from flowing into the TM. This can be accomplished in the following way: The TM is slightly overpressured with an inert gas or nitrogen or the like and the AC gets depressurized to atmospheric pressure. At that point valve 1 opens and the workpiece gets placed into the AC. The LA retracts and valve 1 closes. Now the AC gets pressurized to a pressure that is similar to the PM pressure (at least 1000 psi). This pressurization can occur with SCC, inert gases, nitrogen or the like. Now the workpiece can be moved into the PM. In order to do that valve 2 has to open and the workpiece has to be moved into the PM. Due to the fact that the reach of LA is typically not long enough to move the workpiece from the TM into the AC and into the PM, and due to the fact that valve 1 is closed, an additional workpiece move mechanism has to be applied in order to move the workpiece from the AC to the PM. This mechanism will be explained in great detail in another patent disclosure. But, it should be mentioned here, that such workpiece move devices could comprise of magnetically coupled devices, pneumatic devices, hydraulic devices or the like. After the workpiece has been placed into the PM valve 2 closes and the cleaning process can be begin. To remove the workpiece from the PM, above steps, as explained above, are applied in reverse order.

PM: Process Module. The number of process modules depends on the TPT requirements, but is usually greater than two. To remove the workpieces from the PM, above steps, as explained above in the SWLL section, are applied in reverse order.

Above concept would certainly provide a high TPT system. However, one potential drawback of the system as outlined in Fig. 4 is, that AC's are required.

A simpler way to achieve a high TPT workpiece processing system is outlined as option 3 in Figure 5:

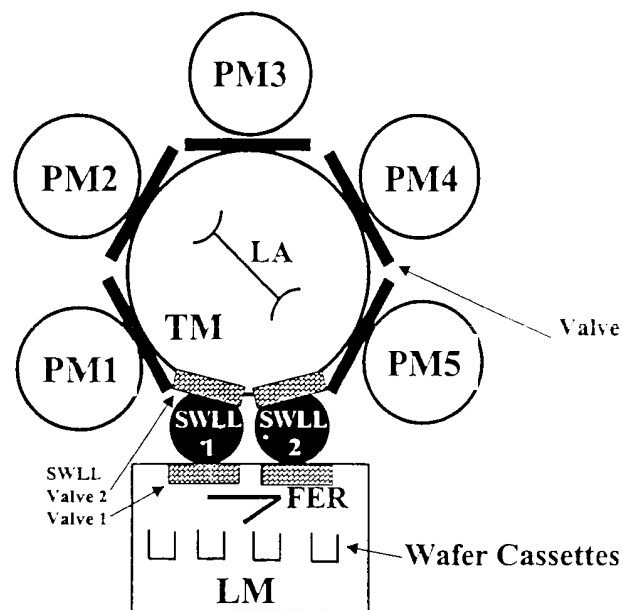


Figure 5: Sketch of option 3 for a workpiece processing system

The workpiece processing flow would be as follows:

LM: Loader Module. Atmospheric module containing a variable number of cassette boxes for wafer sizes greater than 2 inch (e.g.: 3, 4, 5, 6, 8, 12 or greater) , or FOUNDRY OVERLAY PROCESSING boxes for wafer sizes greater than 8 inch or cassettes for flat panel displays of various sizes. For some workpieces proper alignment is required. This alignment can be done in either the LM by adding a (e.g.: a commercially available) workpiece aligner or by aligning the workpieces in one of the processing modules (PM). The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly overpressured with an inert gas or nitrogen or the like).

FER: Front End Robot arm. This robot arm is an atmospheric robot arm. This robot arm can be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the throughput (TPT) of the system by using suction devices such as vacuum or others.

SWLL: Single Wafer Load Lock. The workpiece processing system can contain one, two or more SWLL's, depending on the (backend) configuration and the desired TPT. The purpose of the SWLL is to transfer workpieces from the atmospheric front end to the high pressure backend (supercritical cleaning chambers). The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly

overpressured with an inert gas or nitrogen or the like). In the following an example is given as how to transfer workpieces from the atmospheric front end of the processing system to the high pressure backend.

During the first step of the workpiece transfer the FER picks up a workpiece and transfers it into the SWLL (at that point SWLL Valve 2 is closed. In this configuration valves are not really needed, because the whole front end of the system is under atmospheric pressure and the valve movements described would not be necessary). After the workpiece is in the SWLL, SWLL Valve 1 also closes. Now that the workpiece is in the SWLL the (potentially required) alignment of the workpiece could be performed, if it has not happened yet, in the LM. Pressurization of the SWLL in this case is not required, hence SWLL Valve 2 opens and the Loader Arm (LA) picks up the workpiece. The SWLL in this configuration are considered more like handoff stations rather than SWLL's. The LA could be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the TPT of the system by using suction devices such as vacuum or others. One advantage of having valves on the SWLL's could be though, that sensing devices for PR, PRR and ER could be attached to the SWLL's. By valving off the SWLL before the semiconductor workpiece returns to the cassette, a measurement/sensing cycle could start during which one looks for PR, PRR and ER. If the workpieces were not cleaned completely a warning could occur and the system could be halted or returned into the cleaning cycle.

A more efficient and faster way to transfer the workpieces is described below: The workpiece is transferred via the FER into the SWLL. In this scenario the SWLL(s) do not have SWLL valves, because the backbone is not pressurized, hence no pressurization is required. After the workpiece has been picked up by the FER and placed into the SWLL's / hand off station(s), the (potentially required) alignment of the workpiece could be performed, if it has not happened yet in the LM. In this scenario the SWLL (s) are used solely as handoff and or handoff / alignment stations. Now the Loader Arm (LA) picks up the workpiece. The LA could be a commercially available robot arm purchased from companies such as Brooks Automation, Hines Robotics or else. This robot can transfer wafers by placing them on the (single or dual) end effector held by gravity alone, or it can be a robot arm that increases the TPT of the system by using suction devices such as vacuum or others.

TM: Transfer Module. The purpose of this module is to house the LA which transfers the workpieces to the individual cleaning chambers. The number of ports on the TM can be one or higher. The final number of ports again depends on the (final) system configuration driven by the TPT requirements. A typical number of ports is anywhere between 1 and 6 chambers to warrant a TPT of more than 60 wafers per hour. The transfer module in this scenario is not pressurized (it is in atmosphere, or slightly overpressured with an inert gas or nitrogen or the like. In

this scenario one would most likely prefer to have the TM under slight overpressure in order to avoid contaminants from the PM's flow into the TM)

PM: Process Module. The number of process modules depends on the TPT requirements, but is usually greater than two. Due to the lack of AC's in this configuration, the valves between the TM and PM's are required. A typical load/unload scenario could be envisioned as outlined in the following: The LA has a workpiece on the end effector and is ready to put the workpiece into the PM. Before this can happen the PM has to be depressurized. After the depressurization to atmosphere the valve opens and the LA places the workpiece into the PM. Following that the LA retracts, the valve closes and the PM gets pressurized and the cleaning process starts. In order to unload wafers from the PM(s) one has to apply the same steps as outlined above, in reverse order however.

All three options, as outlined in Section I above, are possible. From a TPT and simplicity point of view however, the latter two options are most likely the preferred ones

Section II: The "integrated" application

In section II a scenario is discussed where the SCC chamber(s) are not used in a standalone application (such as an isolated tool between the etch and the metal deposition process, e.g.). In this application the SCC chamber(s) are attached to existing tool sets already installed in the field (as retrofits), or prior to shipment. It is quite feasible to attach SCC chamber(s) to existing tools such as:

- a) Metal- or oxide etch (cluster) tools
- b) PVD (metal) tools
- c) CVD (metal) tools
- d) PVD/CVD (metal) tools
- e) Electroplating tools
- f) CMP tools
- g) And the like

Attaching SCC chamber(s) to above mentioned tools poses potentially several advantages:

- a) No airbreak between the previous and the cleaning step occurs
- b) No native oxide can form on metal layers (after the oxide etch step and prior to the metal deposition step)
- c) Fewer wafer movements
- d) Fewer tools (if SCC chamber(s) are mounted on existing tools the cleaning tool itself might be obsolete)

In Figure 6 a scenario is sketched where one SCC cleaning chamber is mounted to the backbone of (e.g.) a PVD cluster tool:

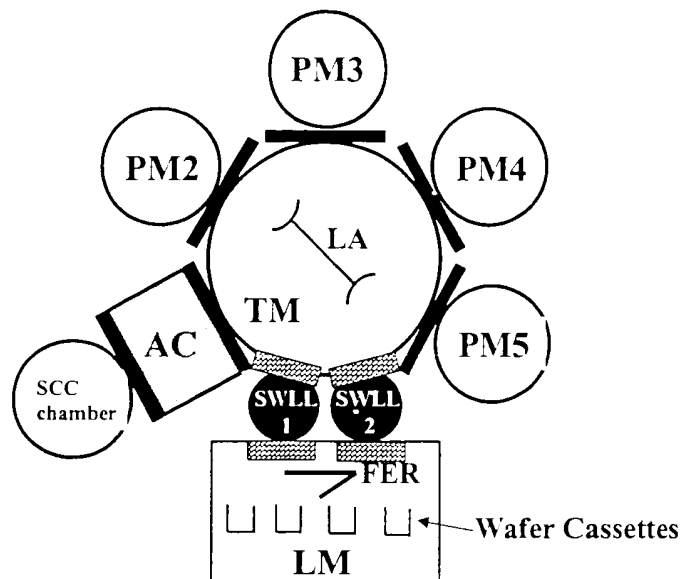


Figure 6: Sketch of the "integrated" solution for a workpiece processing system

As one can see in this case a AC is required, because the pressure conditions in the TM usually do not match the pressure conditions in the SCC chamber (SCCC). In the case of PVD systems for instance, the TM is under high vacuum. In order to make the workpiece transfer as efficient and fast as possible an AC would be used. The process flow in order to move workpieces from the TM into the SCCC and back out would be identical to the workpiece movements (as described earlier):

AC: After the workpieces were placed on the LA and before opening the valve(s) to the AC, pressure equilibrium between the AC and the TM has to be established. In order to do that valve 1 and 2 close and the AC gets depressurized. Preferably to a pressure that is similar to the TM pressure. One might wish though that the TM pressure is slightly higher than then AC pressure, in order to avoid contaminants/particulates from flowing into the TM. Or vice versa, depending in which direction one tries to prohibit the contaminants / particulates to flow. This can be accomplished in the following way: The TM is slightly overpressured/underpressurized with an inert gas or nitrogen or the like and the AC gets depressurized to atmospheric pressure. At that point valve 1 opens and the workpiece gets placed into the AC. The LA retracts and valve 1 closes. Now the AC gets pressurized to a pressure that is similar to the PM pressure (at least 1000 psi). This pressurization can occur with SCC, inert gases, nitrogen or the like. Now the workpiece can be moved into the PM. In order to do that valve 2 has to open and the workpiece has to be moved into the PM. Due to the fact that the reach of LA is typically not long enough to move the workpiece from the TM into the AC and into the PM, and due to the fact that valve 1 is closed, an

additional workpiece move mechanism has to be applied in order to move the workpiece from the AC to the PM. This mechanism will be explained in great detail in another patent disclosure. But, it should be mentioned here, that such workpiece move devices could comprise of magnetically couples devices, pneumatic devices, hydraulic devices or the like. After the workpiece has been placed into the PM valve 2 closes and the cleaning process can be begin. To remove the workpiece from the PM above steps, as explained above, are applied in reverse order.

General comments and Definitions:

1. **The term "clustertool":**

The term clustertool as used in this patent refers to a circular array of processing modules/chambers around a common hub which houses a transfer robot. The linear cluster tool approach will be discussed in a later patent application

2. **The term "workpieces":**

The term workpieces in this patent comprises of: a) semiconductor wafers (Si, SiGe, GaAs based and the like), with wafer sizes ranging from 2 inch to 12 inch and greater, b) optical storage devices (such as CD's, CD ROM's and the like), magnetic storage devices (GMR and the like) and c) flat displays (TFT's and the like)

3. **The term "overpressurized":**

The term overpressurized as used in this patent application is a pressure slightly higher than atmospheric pressure (760 Torr). "Slightly" could mean a range anywhere from 760 Torr to 1000 Torr (and potentially higher). The goal is to prevent particulates (from the surroundings where the cluster tool is situated) entering the cleaning clustertool. The gases used to create this overpressure could be CDA, inert gases, nitrogen or the like

4. **The term "cleaning with SCC":**

The term cleaning with SCC in this patents encompasses the following:

- a) SCC by itself
- b) SCC plus water
- c) SCC plus additives, such as surfactants, solvents or the like
- d) LC by itself
- e) LC plus water
- f) LC plus additives, such as surfactants, solvents or the like